

Tracking and Data Acquisition Elements Research: Polarization Diverse S-Band Feed Cone

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Development of the polarization diverse S-band (PDS) feed cone that is used on the DSS 14 210-ft-diam antenna tricone is described. The PDS system integrates the knowledge gained in two previous feed system developments and provides a highly flexible microwave front end. Right-handed circular polarization, left-handed circular polarization, and orthogonal linear polarizations are available on low-noise listen-only or diplexed channels. Additionally, a research and development radar capability for 500-kW continuous-wave power is provided. The system further provides manual or automatic servo tracking of the position angle of received linear polarization, which will be used for radio science purposes.

I. Introduction

The polarization diverse S-band (PDS) feed cone is a radio-frequency front-end system for the DSIF reflector antennas (85- or 210-ft diam) that provides a flexible polarization capability, low-noise temperature performance, and a high-power transmission capability. Use of improved techniques and field-tested equipment insured an operational system that has very flexible high performance and reliability.

The PDS feed cone uses the fundamental configuration of the S-band multi-frequency (SMF) feed cone previously reported in Refs. 1-3. However, several significant changes

include (1) reduction of waveguide circuitry, (2) modification of RF components from 20- to 500-kW power levels, (3) reduction of total operating noise temperatures T_{op} in all modes, (4) a wide-band feed horn with improved illumination efficiency at the DSIF transmission frequency (Ref. 4), and (5) 500-kW radar capability at the 2388-MHz research and development (R&D) frequency.

The SMF feed cone has been used to support DSS 14 operations since the 1966 station turnon, with only two brief interruptions for *Mariner* planetary encounters. These encounters were characterized by the need for ultra-low-noise receive-only performance in 25°K at the 25-deg

elevation class, which could not be provided by the SMF configuration (Ref. 5). The decision was made to merge, insofar as was possible, the flexible SMF configuration with the ultra-low-noise listen capability and, in May 1970, planning began for installation of the new system as a part of the DSS 14 tricone installation. The new system was to serve, primarily, the multifaceted polarization requirements of the *Pioneer* and *Mariner* families of spacecraft, including occultation and other radio science. Secondary goals were to develop a system capable of reproduction and introduction into the overseas 210-ft-diam antennas, and to provide the future capability of high-power diplexed (500-kW) operations. R&D radar requirements (2388 MHz) and the 500-kW power level were included to reduce costs and the total number of feed cones required for the tricone configuration.

II. Feed Cone Description

The PDS feed cone (Fig. 1) was developed to provide the lowest loss and best physical RF layout with the planned waveguide components. Transmission from the cone is allowed only through the lower orthomode junction port, thus simplifying power handling and isolation

problems with the upper "low-noise port." The single transmitter select switch (SW 3) that combines the DSIF and R&D transmitter outputs further reduces the number of components. Placing the megawatt cassegrain diplexer in the cone provides diplexed modes comparable with the original SMF cone in operation, i.e., either the cone maser or the tricone module III maser can be diplexed. The waveguide switch controller (Fig. 2) is used to position the PDS cone waveguide switches required for the various operating modes. The waveguide paths and polarization selection are presented by an illuminated status display to reduce possible ambiguities with a complex system. All cone operating modes (Table 1) have been carefully safety-interlocked and inhibited through the tricone RF switch controller subsystem. Table 1 includes typical zenith T_{op} values of 18.5 and 23.5°K for the listen-only and diplexed modes, the primary operating modes.

III. Polarization Diversity Operation

The polarization diversity components (Fig. 1) consist of the upper and lower quarterwave plates with three WC504 cylindrical waveguide rotary joints and two drive

Table 1. Operating modes

Mode	Description	Remarks	Switch positions			Polarizer position	Approximate zenith T_{op} , °K (PDS/mod. III traveling wave maser)
			SW 1	SW 2	SW 3		
DSIF							
I	Prime linear listen, ortho transmitter	Ortho linear at mod. III traveling wave maser	2	3	2	4	18.5/29
II	Prime linear, colinear transmitter	Ortho linear at mod. III traveling wave maser	2	1	2	3	23.5/26
III	RCP listen only (star track calibration)	LCP at mod. III traveling wave maser	2	3	2	2	18.5/26
IV	RCP diplex	LCP at mod. III traveling wave maser	2	1	2	1	23.5/26
V	LCP listen only	RCP at mod. III traveling wave maser	2	3	2	1	18.5/29
VI	LCP diplex	RCP at mod. III traveling wave maser	2	1	2	2	23.5/26
VII	Prime linear listen only	Ortho linear at mod. III traveling wave maser	2	3	2	4	18.5/29
R&D							
A	Bistatic radar, DSS 14 receiver	LCP to PDS traveling wave maser, RCP to mod. III traveling wave maser	2	3	2	1	20.6/26
B	Bistatic radar, DSS 14 transmitter	RCP radiated	2	2	3	1	—
C	Monostatic radar	RCP radiated, LCP to PDS traveling wave maser, RCP to mod. III traveling wave maser	2	transmit 2, receive 3	3	1	20.6/26
D	Standby, other cone operative	400-kW transmitter from other cone permitted	2	2	1	any	—

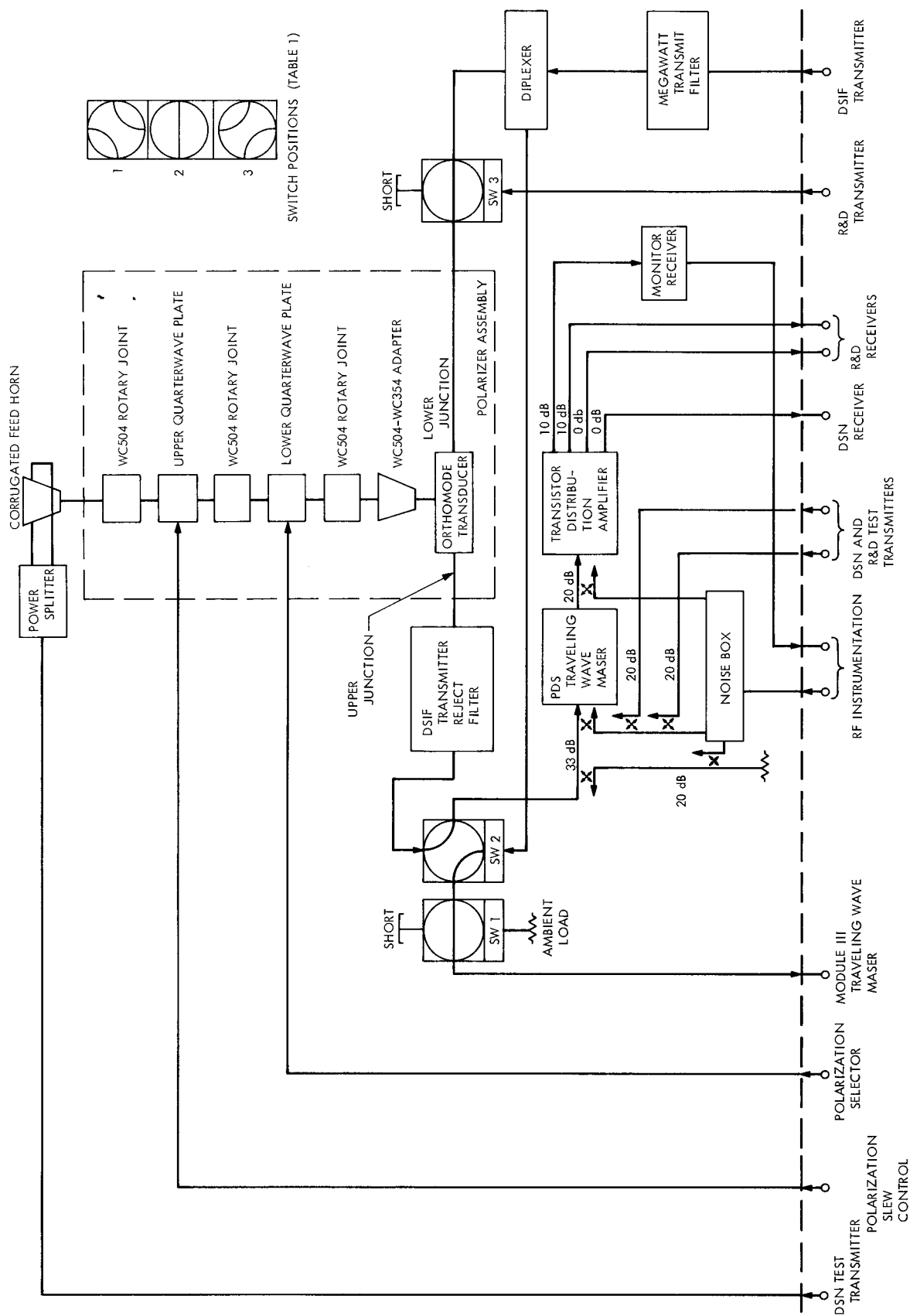


Fig. 1. PDS feedcone block diagram

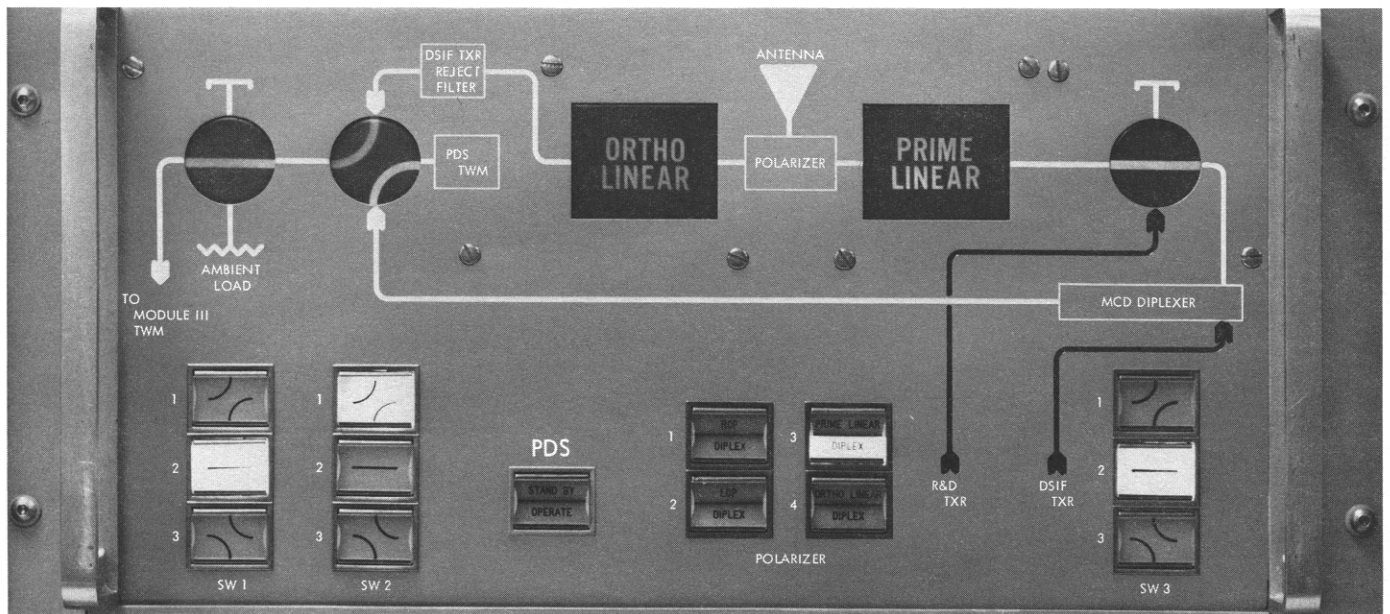


Fig. 2. Control panel, PDS feedcone

motors. Polarization control is accomplished by rotating the quarterwave plates with respect to the orthomode transducer immediately below.

Circular polarizations (CP) are generated by aligning the lower quarterwave plate with the transmitter input port, such that no polarization change is produced; the upper plate is then rotated ± 45 deg to generate the required right-hand circular polarization (RCP) or left-hand circular polarization (LCP) at the horn mouth. Ellipticities of (2.2 ± 0.4) , (0.28 ± 0.28) , and (0.40 ± 0.40) dB are achieved at 2115, 2295, and 2388 MHz, respectively.

The rotating linear polarizations (LP) are generated by aligning the lower quarterwave plate ± 45 deg with respect to the transmitter input port, such that CP signals are produced at the center rotary joint. The upper quarterwave plate then reconverts the CP signals back into linearly polarized waves at the horn mouth. The angular position of these LP waves may be controlled by rotating the upper quarterwave plate. The LP vectors may also be rotated an exact 90 deg by changing the sense of the CP signals from the lower quarterwave plate. This last effect is taken advantage of and used to eliminate a waveguide switch to transfer the signals between the orthomode transducer ports. Ellipticities of (12.5 ± 1.5) , 20.5 (minimum), and approximately 15 dB are achieved at (2100–2120), (2270–2300), and 2388 MHz, respectively.

The polarization changes are implemented with the waveguide switch controller (Fig. 2). Four modes, diplexed RCP, LCP, PRIME LINEAR, and ORTHO LINEAR, are selectable with front panel pushbutton switches. PRIME LINEAR is used to denote the indicated polarization angle (IEEE standard) as readout on a digital display, which is available at a given port. The opposite port will then provide ORTHO LINEAR, i.e., 90-deg spatially oriented from the PRIME. The control of the upper quarterwave plate is switched to the polarization tracking servo unit (Fig. 3) when a linear mode is selected. The polarization tracking servo unit either provides a manual slew mode or polarization autotrack on received position angle of an incoming LP signal, and this is, of course, the prime mode of operation for radio occultation studies of the solar corona transients. Provision within the polarization tracking servo for possible future computer drive is made.

The physical complexity of the original SMF polarization tracking servo unit was vastly simplified by redesign. Two coaxial probes were installed in the feed horn (Fig. 4) to enable alignment of the polarization tracker. The probes provide a receive-band test signal with accurately known position angle. The probes have a coupling coefficient of $(-46$ to $-53)$ and $(-41$ to $-51)$ dB at (2100–2120) and (2270–2300) MHz, respectively.

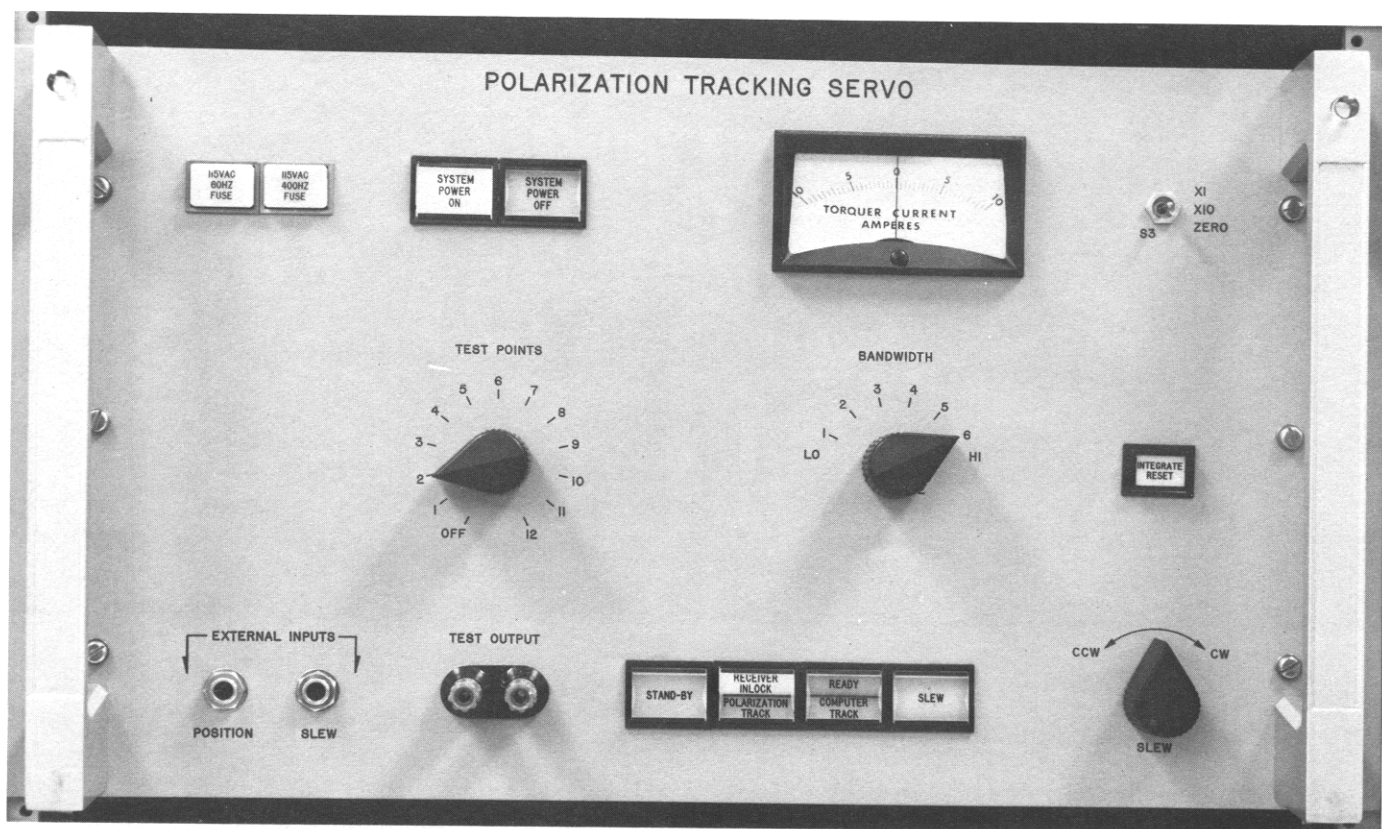


Fig. 3. Polarization tracking servo control unit, PDS feedcone

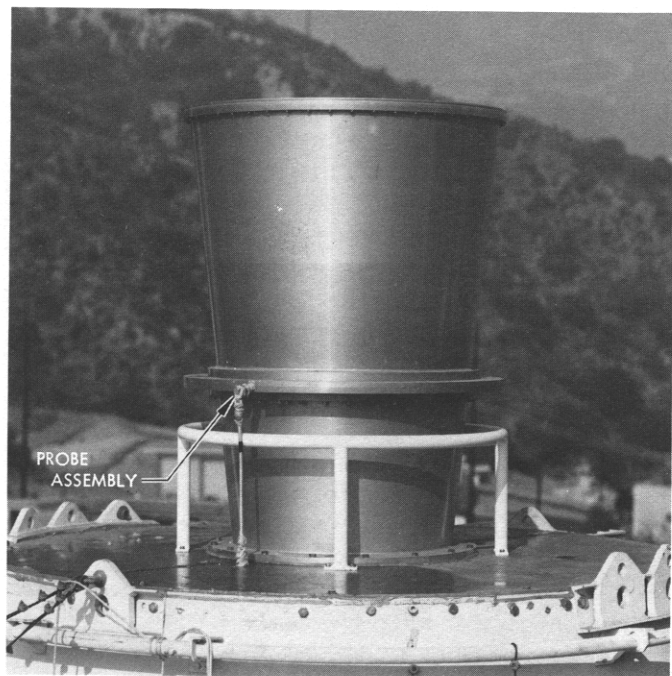


Fig. 4. Alignment probe assembly, PDS feedcone

IV. Waveguide Component Description

Development of the high-power components (Fig. 1) required redesign and high-power testing to insure proper operation. A full description of this work is given in Ref. 6. Basically, all critical parts were made in copper of one-piece construction and liberally water-cooled.

The quarterwave plates are air-cooled because of the difficulty of water cooling continuously rotating equipment reliably. Maximum heat dissipation in this area is approximately 900 W at a 500-kW power level; the air flow is sensed and the transmitters are interlocked OFF in event of an air failure.

Improved choking is utilized in SW 1 and SW 2 to achieve lower insertion loss and improved isolation and match (Ref. 7). SW 3, which handles both high-power transmitter levels, is uniquely water-cooled such that no chance of coolant leakage to the internal waveguides is possible. All waveguide switches use larger rotor-to-stator gaps than previously used, and employ conductive grease on the ball bearings. These measures are thought to

provide improved noise characteristics for waveguide switches.

Figure 5 shows the PDS cone interior, including the orthomode, the diplexer, the transmitter filter, and the lower quarterwave plate drive assembly, and shows the major part of the high-power cooled transmission lines.

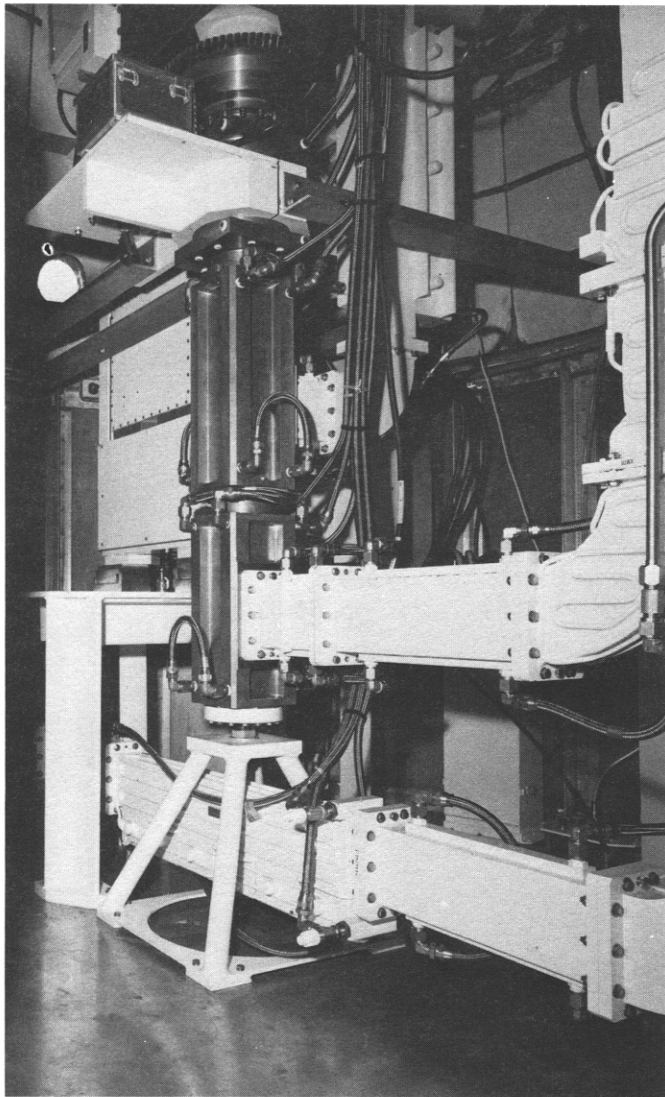


Fig. 5. PDS feedcone interior

The PDS cone construction and initial system measurements were accomplished at JPL on the roof of Building 238. Figure 6 shows the system being readied for shipment to Goldstone.

V. Evaluation

Installation of the PDS cone was made on September 15, 1970. Since that time, the cone has been successfully operated with 200 kW at 2115 MHz, 400 kW at 2388 MHz, and the polarization tracker has been routinely used with the *Pioneer* spacecraft.

Preliminary test results indicate the PDS cone can fulfill the flexible DSN front-end requirements in the S-band range for the near future.

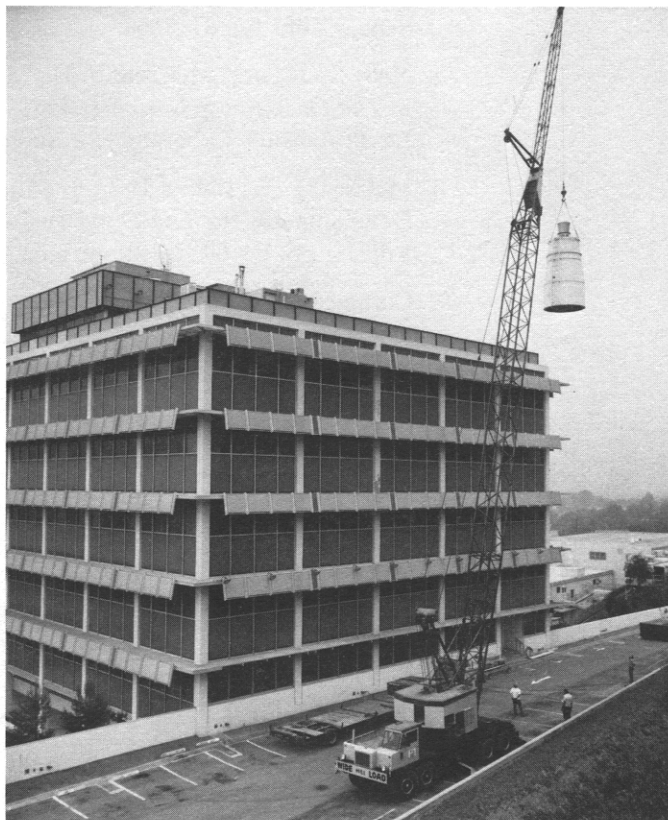


Fig. 6. PDS feedcone shipment

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